Geological Input for the Development of the Paya Terubong-Relau Area, Pulau Pinang

CHOW WENG SUM & FERDAUS AHMAD

Minerals and Geoscience Department Malaysia
Jln Sultan Azlan Shah, 31400 Ipoh, Perak

Abstract

The Paya Terubong – Relau area was investigated to provide geological information to enable development of the area. The results of the investigation will assist town planners to prepare landuse zoning maps and engineers to prepare preliminary construction design.

Input Geologi Untuk Pembangunan Kawasan Paya Terubong-Relau, Pulau Pinang

Abstrak

Kajian kawasan Paya Trubong – Relau dijalankan bertujuan memdapatkan maklumat geologi bagi membolehkan pembangunan di kawasan tersebut. Hasil kajian boleh membantu perancang bandar menyediakan peta zon gunatanah dan jurutera menyediakan rekabentuk pembinaan awal.

INTRODUCTION

The Paya Terubong - Relau area, which is located in the southeastern part of Penang Island is one of the fastest growing areas in Malaysia, as numerous new factories have been constructed in the Bayan Baru Industrial Zone and new housing estates such as the Sun Moon City, have been constructed to cater for the population boom in the area. Hillslopes have been terraced for the construction of numerous high-rise apartments, such as the Saujana Apartment and the Majestic Heights Apartment. The trunk road from Relau to Balik Pulau has also been widened to cater for the heavier traffic volume.

To enable proper development of the area, engineering geological input is essential for town planners to prepare landuse zoning maps and for engineers to prepare preliminary construction designs.

STUDY AREA

The study area which covers 15 km^2 is located about 8 km to the southwest of George Town (Figure 1). Accessibility in the study area is very good as it is highly urbanised with a network of metalled roads transecting the area.

OBJECTIVE AND METHODOLOGY

The main objective of the study is to acquire geological data and create a data bank to cater for the development of the study area. The following investigations were carried out are described in the following sections.

Study of the surface and subsurface geology

Geological mapping was carried out to study the surface geology. To study the subsurface geology, seven holes were bored with a flight auger, three with a guts auger and another three holes were drilled to encounter bedrock. Standard Penetration Tests were also carried out in the 3 drill holes (Figure 2).

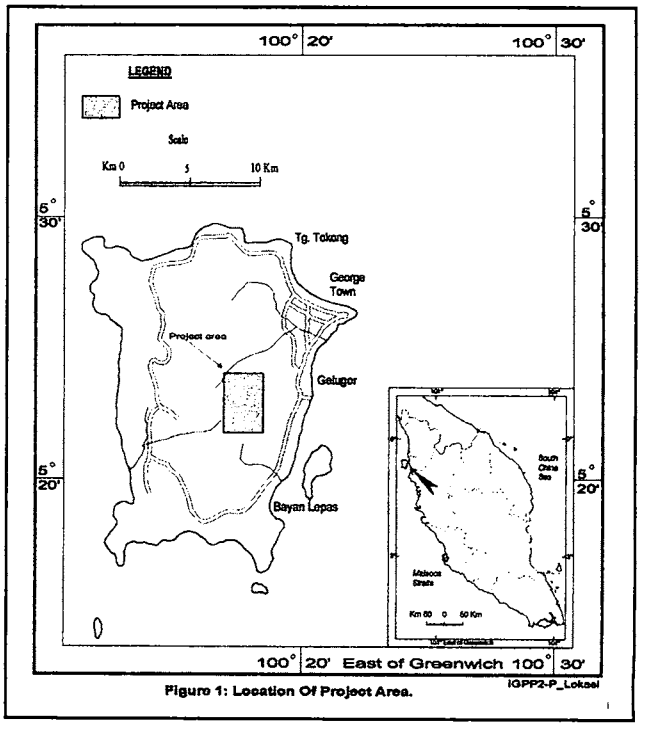

Figure 1: Location of the study area.

Mapping of the terrain

Terrain mapping was carried out to produce thematic maps such as the erosion map, physical constraints map and landuse suitability map.

Study of groundwater potential

A total of 11 shallow wells were drilled by the jetting method. In addition, a drill hole (BH 2) was cased and used as an observation well (Figure 2).

Study of environmental geochemistry

A total of 33 stream water, 20 stream sediment and 10 soil samples were collected and analysed.

RESULTS OF THE INVESTIGATION

Surface geology

Granite occupies about 90% of the study area and the remaining 10%, which is of flat terrain, is covered by

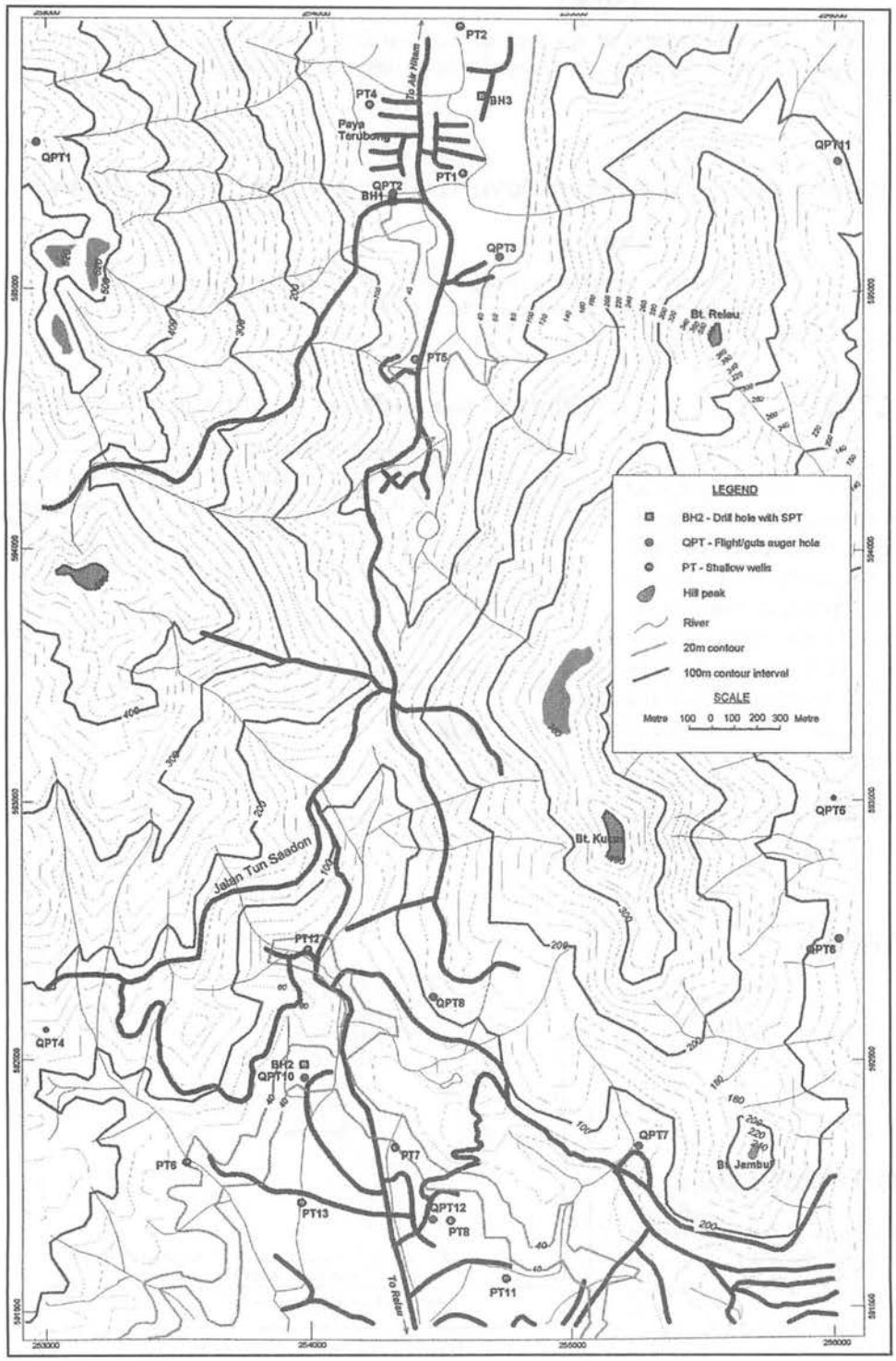

Figure 2: Location of SPT drill holes, guts and flight auger holes and shallow wells.

alluvium (Figure 3). The granite forms moderately steep to steep hills and a number of landslide scars, both observed and interpreted from aerial photographs were demarcated. The numerous clusters of boulders on the hillslopes are probably remnants of debris from the landslides further uphill. Alluvium is present along the Sg. Dondang Valley in the north and along the Sg. Relau Valley in the south of the study area. Numerous lineaments trend in the north-south and northwest-southeast directions. Ong (1993) interpreted the north-south lineaments as major faults.

Subsurface geology

Drill hole BH1 in the Paya Terubong area recorded an uppermost layer of fill material about 3.1 m thick (SPT.N = 15) followed by a layer of residual granitic soil about 4.2 m thick (SPT.N = 15 to 35). Further down is a layer of highly to medium weathered (HW-MW) granitic rocks about 2.2 m thick.

The second drill hole BH2 in the Relau area also recorded an uppermost layer of soft fill material about 2.1m thick (SPT.N = 0) followed by residual granitic soil

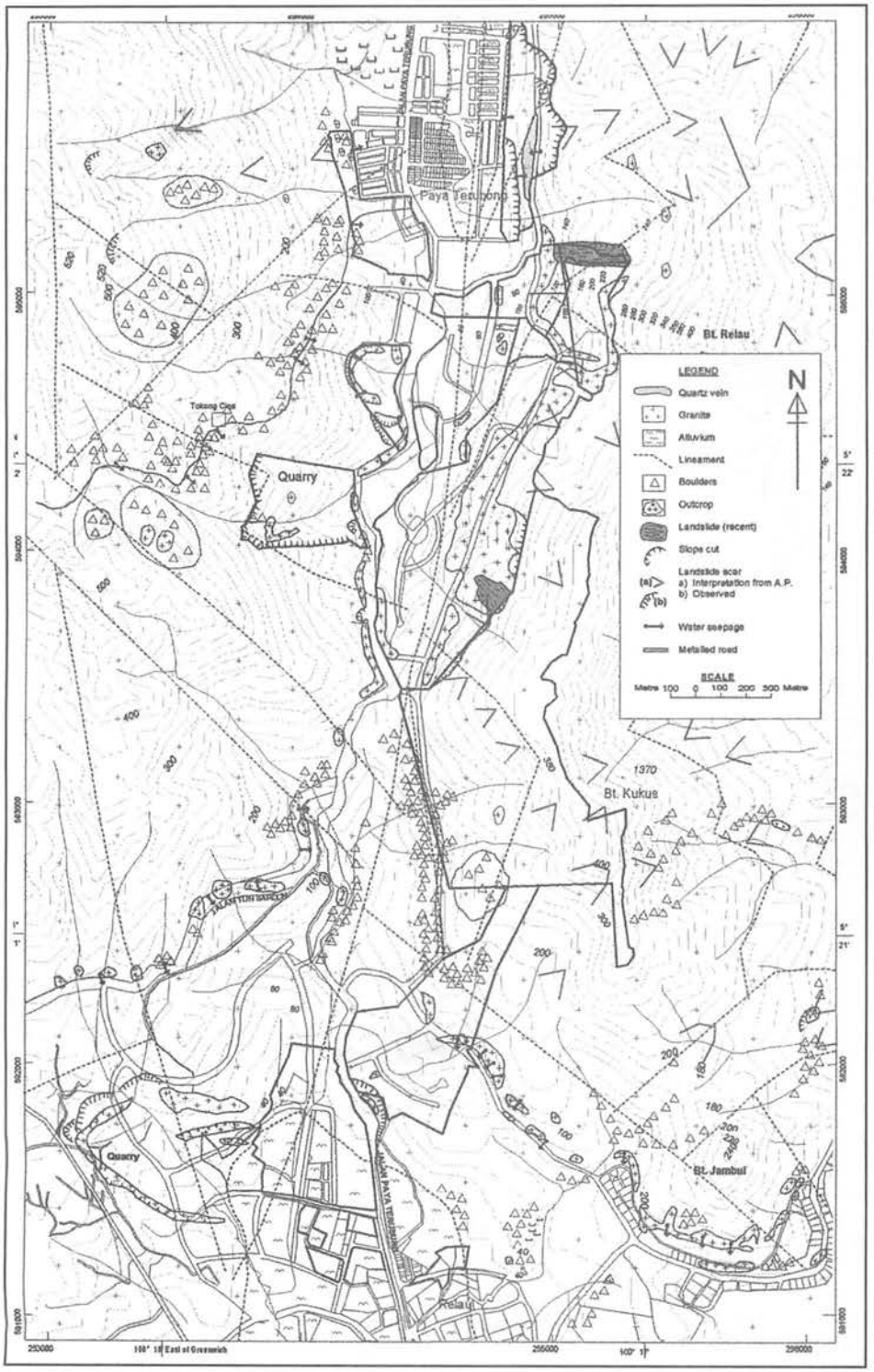

Figure 3: Surface geology of the study area.

of about 4.0 m thick (SPT.N = 32 to 50). Further down is a layer of completely weathered (CW) granite about 3.0 m thick (SPT.N = 50) and HW-MW granite of about 0.7 m thick.

The third drill hole BH3 in the Paya Terubong area recorded an uppermost layer of fill material about 0.9 m thick followed by alluvium of about 3.1 m thick (SPT.N = 4 to 5) and a layer of residual granitic soil about 3.9 m thick (SPT.N = 7 to 11). Beneath the residual soil is slightly weathered to fractured (SW-Fr) granitic rocks.

Terrain mapping

Terrain mapping was carried out in the study area and three thematic maps, viz, the erosion map, the physical constraints map and the landuse classification map were produced.

The soil erosion map (Figure 4) shows that the hilly areas in the southern and western portions of the study area have minor to severe sheet erosion (about 35% of the total area). Another 5% of the total area in the central portion of the study area have moderate to severe rill erosion. Two major landslide scars were observed, with one being located behind Sun Moon City and the other near Majestic Heights Apartment. The remaining portion of the study area has no appreciable erosion.

The physical constraints map (Figure 5) shows that the alluvial flats in Paya Terubong in the north and in Relau in the south are exposed to periodic flash floods. About 30%

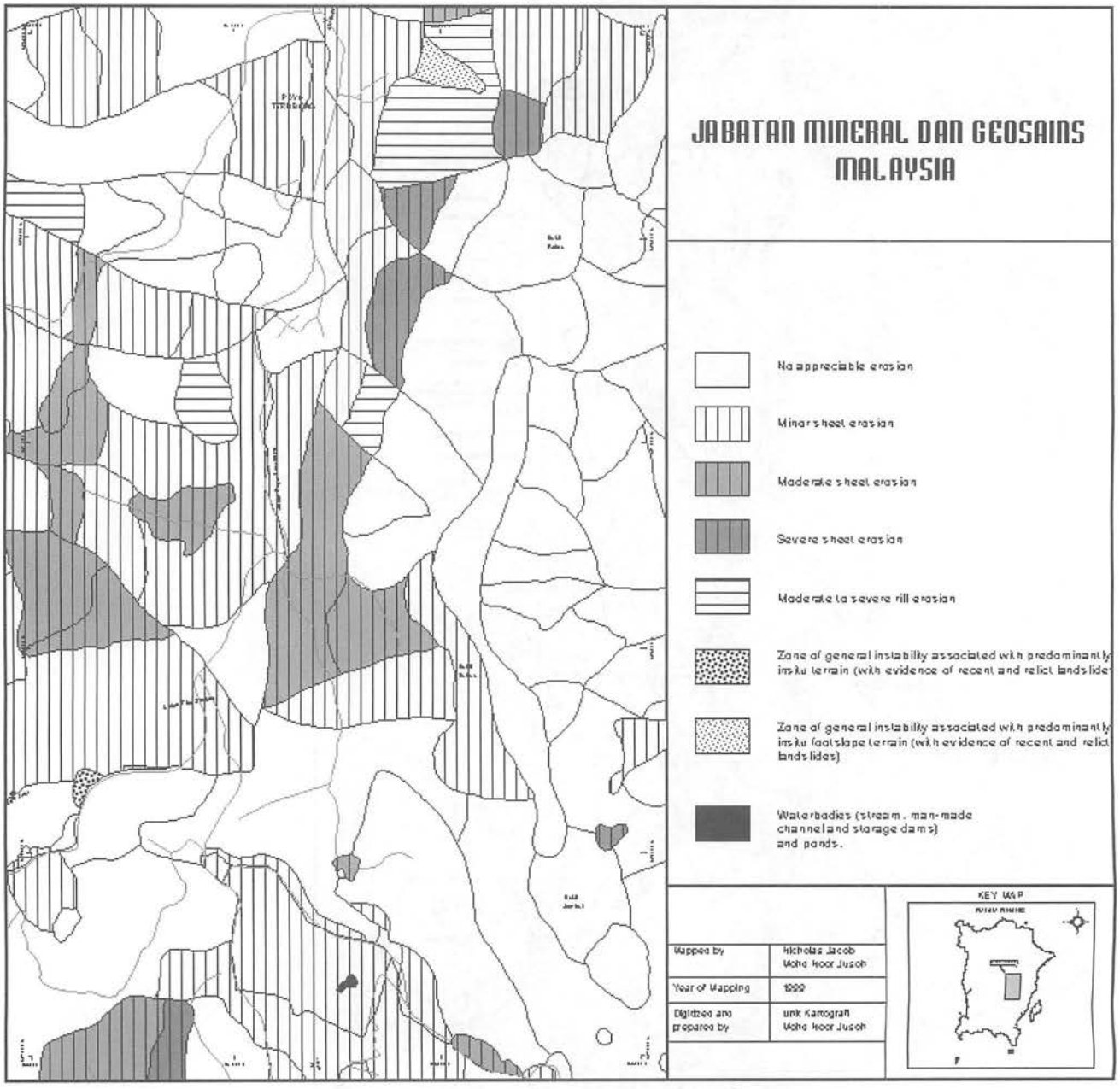

Figure 4: Erosion map of Paya Terubong, Pulau Pinang.

of the study area have steep hill slopes of more than 30° gradient and development on these hill slopes will encounter geotechnical limitations. There are also numerous unstable terraced slopes in the Sun Moon City and Relau areas.

The landuse classification map (Figure 6) shows that Class V type of land, which has extreme geotechnical limitations and requiring very intensive site investigation, (see Table 1) is found on the hill slopes overlooking Jalan Tun Sardon and on the terraced slopes in the southeastern portion of the study area. This class forms about 5% of the study area. Class IV type of land, which has high geotechnical limitations and requiring intensive site investigation is found mainly on the side slopes of hills, forming about 35% of the study area. Class III type of land, which has moderate geotechnical limitations and requiring normal site investigation is found at the foot slope of hills and forms 5% of the study area. The remaining parts of the study area are classified as Classes II and I, which have low geotechnical limitations and requiring only normal site investigation.

Groundwater potential

The groundwater table in the shallow wells in the Paya Terubong area was at a depth of about 1 m below the ground surface whilst that in the Relau area varied between 0.9 m to 2.84 m below the ground surface. However, two of the wells PT7 and PT9 in the Relau area, which had depths of 2.2 m and 6.0 m respectively, were both dry.

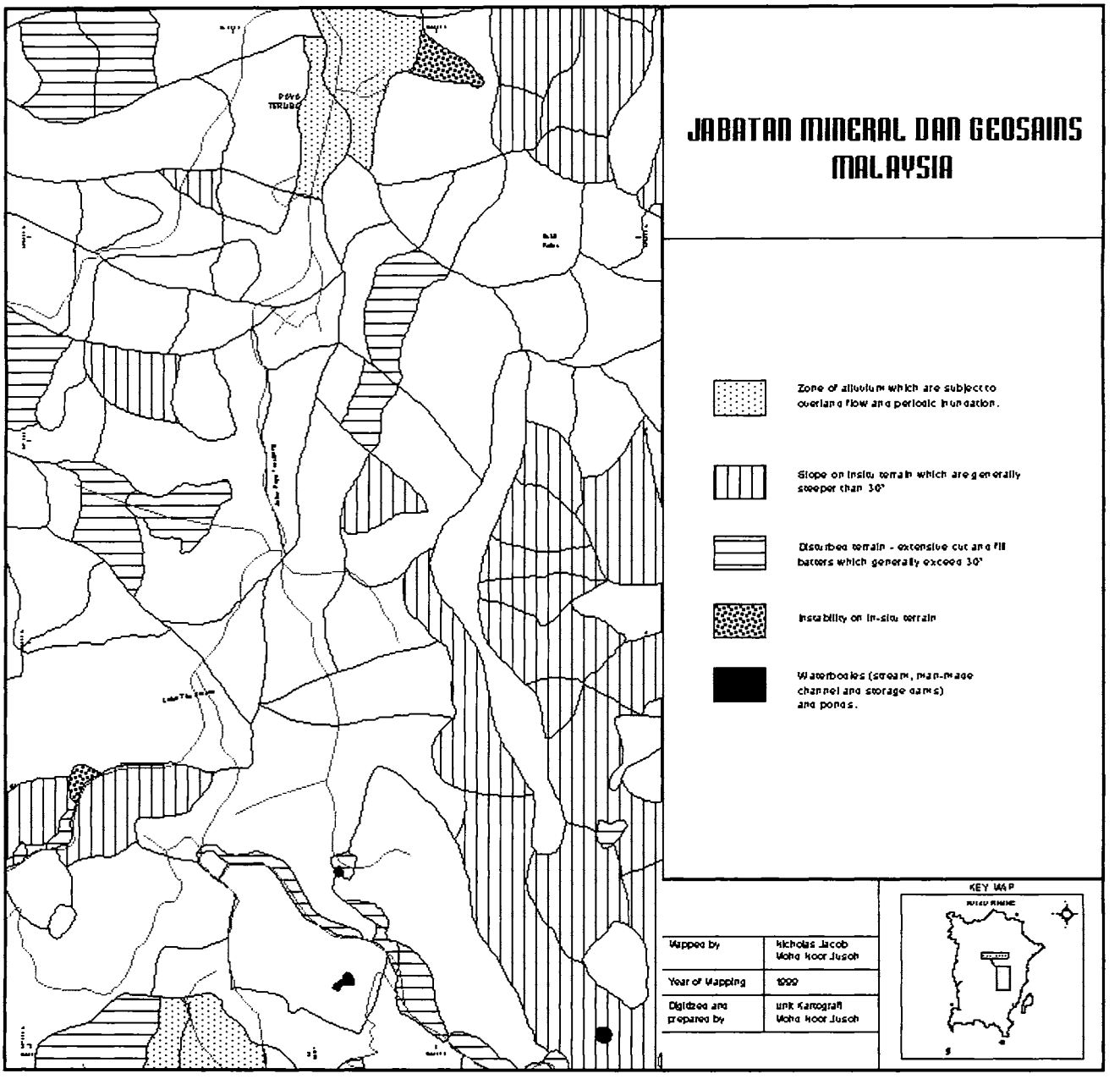

Figure 5: Physical constraints map of Paya Terubong, Pulau Pinang.

Table 1: Landuse classification system (after Hong Kong Geotechnical Engineering Office).

Characteristics of Landuse Classes	Class I	Class II	Class III	Class IV	Class V
Geotechnical Limitations	Low	Low-Moderate	Moderate	High	Extreme
Suitability for Development	High	Moderate	Moderate-Low	Low	Probably Unsuitable
Engineering Costs for Development	Low	Normal	Normal-High	High	Very High
Intensity of Site Investigation Required	Normal	Normal	Normal	Intensive	Very Intensive
Typical terrain characteristics (Some, but not necessarily all of the stated characteristics will occur in the respective class	Gentle slopes and insitu soils. Minor erosion on flatter slopes. Undisturbed terrain (minor cut & fill)	Flat to moderate slopes. Colluvial soils showing evidence of minor erosion. Insitu soils which may be eroded. Reclamation. Rock outcrops. Poor drainage. Cut & fill slopes of low height.	Floodplain subject to periodic flooding and inundation. Moderate slopes colluvial and insitu soils showing evidence of minor to moderate erosion.	Steep slopes. Colluvial & insitu soils showing evidence of severe erosion. Poor drainage. Cut & fill slopes of moderate height.	Combination of characteristics such as steep to very steep slopes, general instability on colluvium, severe erosion, poor drainage, high cut & fill slopes.

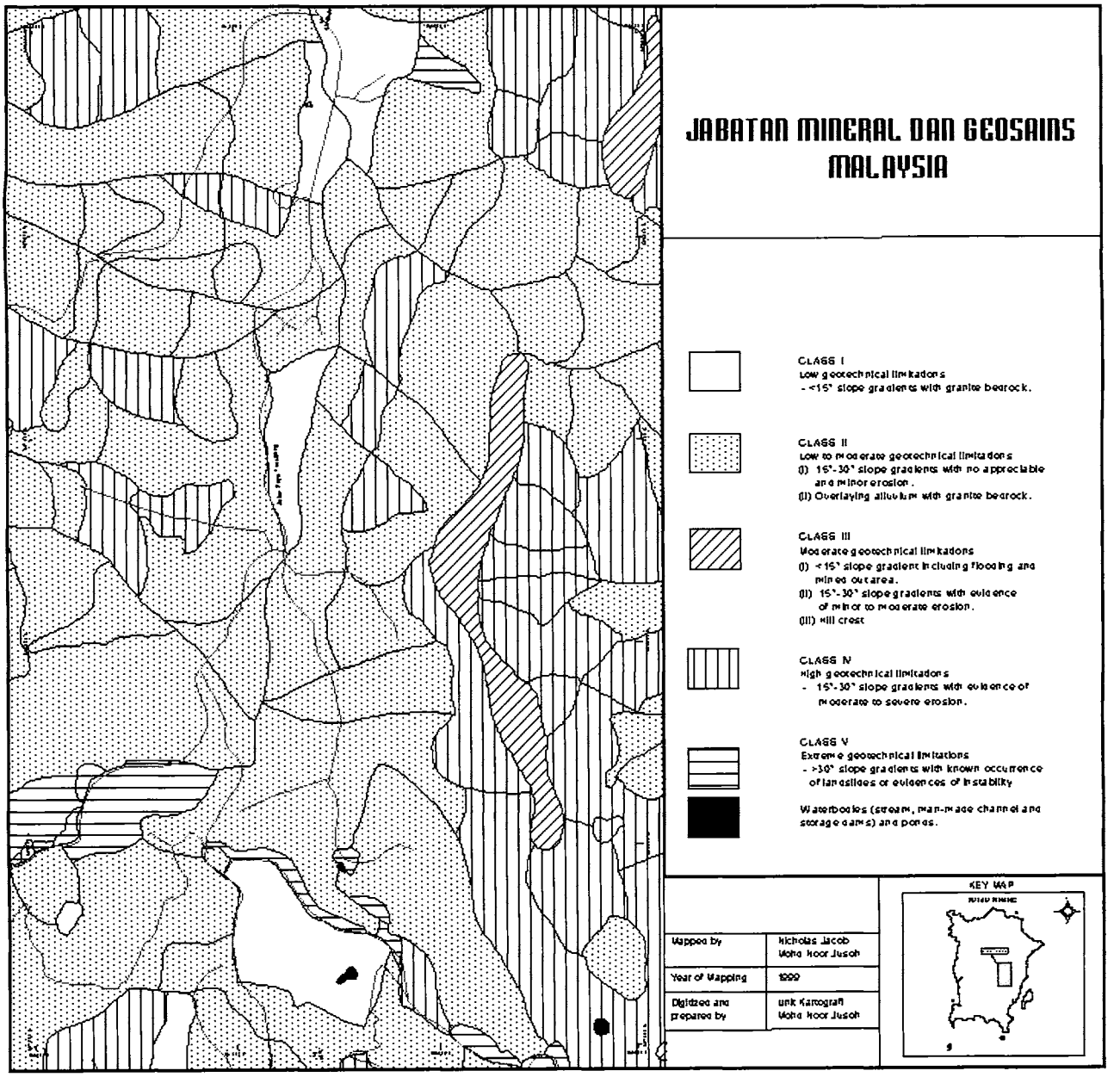

Table 6: Landuse suitability map of Paya Terubong, Pulau Pinang.

Table 2: Characteristics of wells.

Well No.	BH2	PT1	PT2	PT4	PT5	PT6	PT7	PT8	PT9	PT11	PT12	PT13
Depth of hole (m)	11.7	6.3	8.1	0.7	8.0	10.5	2.2	14.0	6.0	6.0	2.1	10.0
Depth of well (m)	6.1	5.8	7.8	-	7.2	6.0	2.0	5.8	5.8	3.8	1.8	7.2
Collar height (m)	0.3	0.28	1.06	-	0.29	0.28	0.27	0.24	0.25	0.27	0.38	0.77
Screen depth (m)	4.8-5.8	3.8-5.3	5.8-7.3	-	5.7-7.2	4.0-5.5	1.0-2.0	3.8-5.3	3.8-5.3	1.8-3.3	0.8-1.8	5.7-6.7
Production (l/hr)	1000	2000	2000	-	1000	1000	0	1000	0	1000	1000	2000

Table 3: Results of chemical analyses of groundwater.

Table 3. Results of chemical analyses of groundwater

Well No.	Fe (mg/L)	Mn mg/L)	Cu (mg/L)	Pb (mg/L)	Zn (mg/L)	Ni (mg/L)	Cd (mg/L)	Sr (mg/L)	Ba (mg/L)	Se (mg/L)	Cr (mg/L)	Cn (mg/L)	Hg (ug/L)
PT 1	45.0	0.5	<0.1	0.01	<0.1	<0.1	<0.01	0.03	0.1	<0.005	<0.01	<0.5	0.50
PT 2	23.0	0.4	<0.1	0.07	0.2	<0.1	<0.01	<0.01	0.2	<0.005	0.02	<0.5	0.30
PT 5	1.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	<0.01	<0.5	0.50
PT 6	14.0	0.3	<0.1	<0.01	<0.1	<0.1	<0.01	0.04	0.2	<0.005	<0.01	<0.5	0.70
PT 8	8.5	0.2	<0.1	<0.01	<0.1	<0.1	<0.01	0.01	<0.1	<0.005	<0.01	<0.5	<0.20
PT 11	5.5	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	0.01	<0.1	<0.005	<0.01	<0.5	<0.20
PT 12	15.0	0.3	0.1	0.01	0.2	<0.1	<0.01	0.02	0.2	<0.005	<0.01	<0.5	<0.20
PT 13	23.0	<0.1	<0.1	0.11	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	<0.01	<0.5	0.50
BH 2	8.1	0.8	<0.1	<0.01	<0.1	<0.1	<0.01	0.04	<0.1	<0.005	<0.01	<0.5	<0.20
WHO / MOH # Std.	0.3	0.1	1	0.05	5	-	0.003	-	-	0.01	0.05	0.07	1.0

Well No.	Ca (mg/L)	Mg mg/L)	Na (mg/L)	K (mg/L)	CO_3 (mg/L)	HCO_3 (mg/L)	CL (mg/L)	SO_4 (mg/L)	NO_3 (mg/L)	F (mg/L)	PO 4 (mg/L)	As (mg/L)	Al (ug/L)	NH 4 (ug/L)
PT 1	8.9	4.3	16.0	9.0	<1	74	9	<3	11.4	<0.5	0.06	0.026	<0.1	<0.50
PT 2	3.5	0.5	7.6	2.9	<1	19	6	9	2.5	<0.5	0.05	0.017	<0.1	<0.50
PT 5	2.7	0.5	8.3	2.0	<1	27	6	<3	2.4	<0.5	0.05	0.008	<0.1	<0.50
PT 6	2.7	2.1	10.0	4.4	<1	37	4	<3	3.3	<0.5	0.05	0.012	<0.1	<0.50
PT 8	2.7	1.6	6.5	4.6	<1	<1	14	5	16.2	<0.5	0.05	<0.005	<0.1	1.50
PT 11	3.5	<0.1	4.4	1.7	<1	21	4	<3	0.7	<0.5	0.36	<0.005	<0.1	<0.50
PT 12	0.9	0.5	7.5	1.7	<1	16	6	<3	<0.5	<0.5	0.43	<0.005	<0.1	<0.50
PT 13	2.7	2.1	8.6	3.6	<1	11	10	<3	25.1	<0.5	0.03	0.023	<0.1	<0.50
BH 2	33.00	1.0	8.2	8.7	<1	130	<1	6	1.0	<0.5	0.04	0.015	<0.1	<0.50
WHO / MOH # Std.	-	150 #	200 #	-	-	-	250	400	45	1.5	0.2 #	0.05	0.2	-

Well No.	Temp. (C)	pH (F)*	pH (L)*	Con.* (F)* (uS/cm)	Con.* (L)* (uS/cm)	Colour (H.U.)	Turbidity (N.T.U.)	TDS (mg/L)	DS (mg/L)	SiO 2 (mg/L)	"Detergent * (mg/L)	SAR
PT 1	28.5	6.4	6.2	320	164	5	85	192	96	28	<0.25	1.10
PT 2	28.5	7.2	6.5	73	63	5	3225	3796	46	28	<0.25	1.01
PT 5	28.8	6.3	6.4	57	54	5	9	106	54	43	<0.25	1.22
PT 6	28.6	6.7	6.3	147	87	5	34	74	58	33	<0.25	1.11
PT 8	29.5	6.4	4.5	142	105	5	73	268	98	42	<0.25	0.77
PT 11	28.1	6.5	5.9	68	43	5	136	190	50	29	<0.25	0.65
PT 12	31.1	7.9	6.3	46	37	10	2275	4236	62	28	<0.25	1.57
PT 13	28.6	6.0	6.0	194	94	10	134	388	96	51	<0.25	0.96
BH 2	29.0	6.2	7.0	257	224	5	179	392	158	16	<0.25	0.38
WHO / MOH # Std.	-	6.5-8.5	6.5-8.5	-	-	15	5	-	-	-	-	-

Note: WHO Standards - World Health Organisation Drinking Water Standards (1984)
MOH Standards - Malaysian Ministry of Health Drinking Water Standards (1992)
(F) * - Value measured in field
(L) * - Value measured in laboratory
Con.* - Conductivity

(Difference in pH and conductivity values in the field and in the laboratory is normal and expected)

Pumping tests carried out on the remaining 10 wells showed that the wells could only yield between 1000 to 2000 litres/hr and as such, there is very little potential in the utilisation of groundwater for water supply (Table 2).

The groundwater in these wells contained high Fe contents (Table 3), varying from 1.1 ppm in PT5 to as high as 45.0 ppm in PT1 (as compared to the WHO allowable limit of 0.3 ppm). The concentration of Mn in six of the wells (PT1, PT2, PT6, PT8, PT12 and BH 2) were high, varying from 0.2 to 0.8 ppm (as compared to the WHO allowable limit of 0.1 ppm). The concentration of phosphate in two wells, PT11 and PT12 were high, measuring 0.36 ppm and 0.44 ppm respectively (as compared to the WHO allowable limit of 0.2 ppm). This could be due to the usage of fertilisers from nearby agricultural activities. The concentration of Pb in two wells, PT2 and PT13 measured 0.07 ppm and 0.11 ppm respectively, which were also above the WHO allowable limit of 0.05 ppm.

Environmental Geochemistry

Stream water

Chemical analyses conducted on stream water showed that the amount of Hg in 16 samples (Table 4) was less than 0.2 ppb, 15 samples had concentrations between 0.3 to 24 ppb and 2 samples (IPP05 and IPP06 on a tributary of Sg. Relau) had very high Hg concentrations of 238 ppb and 485 ppb. These two samples were collected from an agricultural area and there were two operating quarries nearby.

The COD values for most samples were high and only 5 (IPP10, IPP27, IPP30, IPP31 and IPP32) had low COD values varying from 0 to 44 ppm.

The concentration of nitrate in the stream water was generally low, except for samples IPP26 and IPP31 along Sg. Dondang which had higher values of 10.1 ppm and 9.1 ppm respectively.

Stream sediments

Results show that the stream sediments generally have low concentrations of metallic contents except for Ca, Mg and K (Table 5). The concentration of Ca in the stream sediments varied between 133 to 1520 ppm, Mg, between 233 to 780 ppm and K, between 250 to 952 ppm.

Soil samples

Soil samples collected from the B-horizon were analysed and results show that except for Ca, Mg and K, the concentrations of all other metallic contents were low (Table 6).

The concentration of Ca varied from 68 to 828 ppm, Mg, between 268 to 970 ppm and Mg, 364 to 908 ppm.

GEOTECHNICAL ASSESSMENT

The terrain maps are useful for town planners and engineers. Areas with high erosion should be investigated to verify the causes and to identify the proper mitigation measures to be undertaken.

Development in areas classified as Classes V and IV in the landuse classification map should be stringently controlled and intensive detailed site investigation should be enforced prior to the design of the layout and foundation plans.

As a guide, Standard Penetration Tests (SPT) carried out show that the depth to attain N = 50 values varied between 3.0 m to 7.3 m deep within the HW zone of the residual granitic soil.

There are numerous clusters of granite boulders on the hill slopes and these boulders are remnant debris of former landslides further uphill. Some of the boulders are also buried within the soft colluvium at the foothills. As such detailed mapping should be carried out to identify colluvial areas.

There is little potential for the abstraction of groundwater as a resource for water supply as the wells could only produce between 1000 to 2000 litres/hour. Also, the groundwater has high Fe and Mn contents and to utilise the groundwater for drinking purposes, treatment is necessary.

There is no serious contamination in the stream water, stream sediments and residual soil. However, stream water in a tributary of Sg. Relau has high concentrations of Hg and Sg. Dondang has high nitrate levels. Generally, the stream water is clean enough to be used for drinking purposes after treatment by conventional methods.

CONCLUSION

Terrain maps of the study area serve as a useful guide for town planners in the preparation of landuse zoning maps and for the approval of development projects. The surface and subsurface geological data will be of use to engineers in the design of layout and foundation plans.

Geochemical data of the groundwater, stream water, stream sediments and residual soil will serve as a useful reference for future environmental auditing of the area.

REFERENCES

Abd. Majid Sahat, Nurzaidi, A. and Chow, W.S., 1998. Kegagalan Cerun di Taman Sun Moon City, Paya Terubong. *Jabatan Penyiasatan Kajibumi Laporan* E(F)5/98.

Abdullah, S., 2000. Kajian Ketebalan Lapisan Tanah Baki Bagi Projek Kajian Integrasi Geologi Kawasan Paya Terubong - Relau, Pulau Pinang. *Jabatan Penyiasatan Kajibumi Laporan* QT2/00.

Ahmad Zulkifli, K., 2000. Seismic Refraction Survey As Part of An Integrated Geological Study At Paya Terubong - Relau Area, Penang. *Geol. Surv. Dept. Report* No. GF 4/00.

Aktiviti Geologi Kejuruteraan, 2000. Penyiasatan Geologi Kejuruteraan Kawasan Paya Terubong - Relau, Pulau Pinang. *Jabatan Penyiasatan Kajibumi Laporan* E(F)1/00.

Chand, F., 1981. A Manual of Geochemical Exploration Methods. *Geol. Surv. Dept. Special Paper* 3. Geological Survey Malaysia.

Table 4: Results of chemical analyses conducted on stream water.

NO	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	NO_3	F	P	As	Al	NH_4	Fe	Mn	Cu	Pb	Zn	Ni	Cd	Sr	Ba	Se	B
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
IPP01	1.9	0.4	6.4	2.2	<1	12	3	<3	<0.5	<0.5	0.03	<0.005	0.8	0.7	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP02	1.6	0.6	6.0	1.4	<1	19	2	<3	3.8	<0.5	0.06	<0.005	0.2	2.2	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP03	1.0	0.3	5.3	1.5	<1	13	2	<3	6.7	<0.5	<0.02	<0.005	0.2	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP04	1.5	0.4	6.0	2.8	<1	10	3	<3	5.0	<0.5	0.03	<0.005	0.3	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP05	1.3	0.3	5.7	1.4	<1	13	3	<3	4.3	<0.5	0.03	<0.005	0.2	3.3	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP06	0.4	0.1	5.4	1.6	<1	12	4	<3	2.2	<0.5	<0.02	<0.005	0.3	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP07	1.0	0.2	3.7	1.9	<1	11	<1	<3	4.8	<0.5	0.08	<0.005	0.3	1.7	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP08	0.7	0.2	3.3	1.9	<1	7	3	<3	4.9	<0.5	0.03	<0.005	0.3	3.1	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP09	1.5	0.4	5.3	2.8	<1	7	4	<3	2.7	<0.5	0.03	<0.005	0.4	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	
IPP10	0.6	0.1	3.5	1.8	<1	8	2	<3	5.2	<0.5	<0.02	<0.005	0.3	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP11	53.0	0.6	5.8	2.7	<1	23	2	<3	3.3	<0.5	0.08	<0.005	0.5	<0.5	0.3	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	0.02	<0.1	<0.005	-
IPP12	4.4	0.5	3.8	2.2	<1	18	3	<3	3.1	<0.5	0.05	<0.005	0.3	<0.5	0.2	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	0.01	<0.1	<0.005	-
IPP13	2.1	0.3	4.3	1.8	<1	13	3	<3	2.2	<0.5	0.05	<0.005	0.4	<0.5	0.2	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	0.01	<0.1	<0.005	-
IPP14	5.7	0.7	7.3	2.9	<1	25	5	<3	2.9	<0.5	0.31	<0.005	0.3	1.1	0.4	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	0.02	<0.1	<0.005	-
IPP15	1.2	0.3	6.1	1.4	<1	11	3	<3	1.6	<0.5	0.09	<0.005	0.3	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP16	1.0	0.3	6.5	0.8	<1	10	3	<3	0.8	<0.5	0.05	<0.005	0.3	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP17	1.6	0.4	6.2	2.1	<1	15	3	<3	1.6	<0.5	0.13	<0.005	0.4	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP18	2.4	0.4	6.4	1.0	<1	10	4	<3	1.3	<0.5	0.17	<0.005	0.4	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP19	3.6	0.7	8.1	2.5	<1	17	8	5	3.5	<0.5	0.14	<0.005	0.3	<0.5	0.4	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	0.01	<0.1	<0.005	-
IPP20	0.8	0.3	6.3	0.6	<1	7	4	<3	1.9	<0.5	0.11	<0.005	0.4	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP21	0.6	0.3	6.5	0.6	<1	7	3	<3	2.5	<0.5	0.05	<0.005	0.2	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP22	3.7	0.5	7.1	2.3	<1	22	5	<3	1.4	<0.5	1.10	0.006	0.5	0.7	0.4	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	0.01	<0.1	<0.005	-
IPP23	2.4	0.3	6.1	1.5	<1	19	2	<3	5.2	<0.5	0.28	<0.005	0.5	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP24	2.2	1.8	18.0	3.1	<1	87	18	5	1.7	<0.5	0.75	<0.005	0.4	3.7	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP25	2.1	0.3	3.9	1.9	<1	11	2	<3	2.0	<0.5	0.13	<0.005	0.5	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	0.01	<0.1	<0.005	-
IPP26	2.2	0.3	4.9	1.8	<1	10	4	<3	10.1	<0.5	<0.02	0.019	0.4	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP27	10.0	0.8	12.0	3.6	<1	22	8	8	2.0	<0.5	0.89	0.008	0.3	3.9	1.1	0.2	<0.1	<0.01	0.1	<0.1	<0.01	0.02	<0.1	<0.005	-
IPP28	1.2	0.2	4.4	1.7	<1	12	2	<3	1.3	<0.5	<0.02	<0.005	0.4	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP29	8.6	0.7	10.0	3.5	<1	25	7	7	2.5	<0.5	0.59	0.007	0.3	4.0	0.6	0.1	<0.1	<0.01	<0.1	<0.1	<0.01	0.02	<0.1	<0.005	-
IPP30	10.0	1.3	11.0	6.1	<1	25	7	7	3.9	<0.5	1.80	0.007	0.3	6.5	0.5	0.2	<0.1	<0.01	0.1	<0.1	<0.01	0.03	<0.1	<0.005	-
IPP31	1.2	0.3	3.8	2.0	<1	10	3	<3	9.1	<0.5	<0.02	<0.005	0.4	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP32	0.7	0.2	6.2	2.2	<1	10	4	<3	1.5	<0.5	0.05	<0.005	0.3	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
IPP33	3.8	0.4	4.7	2.4	<1	19	3	<3	5.3	<0.5	0.16	<0.005	0.5	<0.5	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.1	<0.005	-
Minimum	0.4	0.1	3.3	0.6	<1	7	2	5	0.8	<0.5	0.03	0.006	0.2	0.7	0.2	0.1	<0.1	<0.01	0.1	<0.1	<0.01	0.01	<0.1	<0.005	-
Maximum	53.0	1.8	18.0	6.1	<1	87	18	8	10.1	<0.5	1.80	0.019	0.8	6.5	1.1	0.2	<0.1	<0.01	0.1	<0.1	<0.01	0.03	<0.1	<0.005	-
Average	4.1	0.5	6.4	2.1	<1	16	4	6	3.4	<0.5	0.27	0.009	0.4	2.8	0.5	0.2	<0.1	<0.01	0.1	<0.1	<0.01	0.02	<0.1	<0.005	-

Note : DET: Detergent; CHR : Carbonate Hardness; HAR : Hardness; SUS : Suspended Solid; ALK : Total Alkalinity; NCH : Non-Carbonate Hardness

Table 4(continued): Results of chemical analyses conducted on stream water.

NO	Cr	Ag	Bi	Co	Mo	Sb	pH	Colour	Turb.	COND.	SiO_2	T_Solid	D_Solid	NO_2	CN	Hg	DET	SUS	HAR	ALK	CHR	NCH	BOD	COD	DO
	ppm	ppm	ppm	ppm	ppm	ppm		H.U	N.T.U	umhos/cm	ppm	mg/l	mg/l	ppm	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm	mg/l	mg/l	mg/l
IPP01	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.0	5	5.9	47	15	50	44	0.006	<0.05	0.2	<0.25	6	6	20	6	0	2.2	135	4.0
IPP02	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.0	5	5.3	44	17	54	44	<0.005	<0.05	<0.2	<0.25	10	6	31	6	0	2.5	130	4.8
IPP03	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.3	5	3.4	37	15	46	42	<0.005	<0.05	<0.2	<0.25	4	4	21	4	0	0.9	H/R	4.9
IPP04	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.1	5	8.1	51	14	52	34	<0.005	<0.05	<0.2	<0.25	18	5	16	5	0	1.4	H/R	5.4
IPP05	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.9	5	7.8	39	13	54	46	<0.005	<0.05	238.0	<0.25	8	4	21	4	0	1.5	159	5.1
IPP06	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.5	5	2.0	33	15	40	38	<0.005	<0.05	485.0	<0.25	2	1	20	1	0	0.8	89	4.7
IPP07	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.1	5	16.0	31	11	54	34	<0.005	<0.05	24.0	<0.25	20	3	18	3	0	1.1	150	5.3
IPP08	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.0	5	7.2	29	10	34	28	0.006	<0.05	11.0	<0.25	6	3	11	3	0	1.6	161	5.4
IPP09	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.1	5	8.5	48	10	56	28	0.006	<0.05	7.6	<0.25	28	5	11	5	0	0.5	136	4.9
IPP10	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.9	5	10.0	26	10	52	32	0.006	<0.05	7.6	<0.25	20	2	13	2	0	1.8	-	6.4
IPP11	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.2	5	38.0	67	11	86	54	<0.005	<0.05	11.0	<0.25	32	16	38	16	0	1.7	160	4.2
IPP12	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.3	5	53.0	49	10	106	34	<0.005	<0.05	2.1	<0.25	72	13	30	13	0	0.5	160	5.2
IPP13	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.2	5	10.0	39	9.8	52	34	<0.005	<0.05	<0.2	<0.25	18	6	21	6	0	2.1	165	4.2
IPP14	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.7	5	11.0	78	13	82	68	<0.005	<0.05	7.2	<0.25	14	17	41	17	0	2.6	165	4.0
IPP15	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.0	5	6.9	38	16	42	38	<0.005	<0.05	0.8	<0.25	4	4	18	4	0	2.3	156	4.8
IPP16	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.0	5	18.0	37	13	64	34	0.007	<0.05	1.8	<0.25	30	4	16	4	0	1.2	164	5.5
IPP17	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.2	5	8.5	46	16	54	34	<0.005	<0.05	0.3	<0.25	20	6	25	6	0	1.2	150	6.2
IPP18	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.0	5	18.0	48	12	56	52	<0.005	<0.05	2.7	<0.25	4	8	16	8	0	1.9	160	4.3
IPP19	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.9	5	4.9	71	17	68	60	<0.005	<0.05	0.3	<0.25	8	12	28	12	0	0.2	H/R	4.3
IPP20	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.1	5	9.3	36	14	52	40	<0.005	<0.05	<0.2	<0.25	12	3	11	3	0	0.2	160	6.6
IPP21	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.1	5	8.7	36	14	56	32	<0.005	<0.05	<0.2	<0.25	24	3	11	3	0	1.5	160	6.6
IPP22	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.7	5	15.0	62	14	76	60	<0.005	<0.05	<0.2	<0.25	16	11	36	11	0	1.3	164	4.8
IPP23	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.4	5	2.3	44	17	54	54	<0.005	<0.05	<0.2	<0.25	0	7	31	7	0	1.3	162	4.3
IPP24	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.2	5	16.0	278	16	100	90	0.006	<0.05	<0.2	<0.25	10	13	143	13	0	0.7	H/R	5.4
IPP25	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.9	5	50.0	40	11	162	28	<0.005	<0.05	<0.2	<0.25	134	6	18	6	0	1.5	H/R	5.0
IPP26	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.3	5	6.3	44	11	48	36	0.006	<0.05	<0.2	<0.25	12	7	16	7	0	2.1	148	4.6
IPP27	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.3	5	4.8	143	11	110	82	0.008	<0.05	<0.2	<0.25	28	28	36	28	0	0.1	44	3.8
IPP28	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.0	5	32.0	34	12	72	46	<0.005	<0.05	<0.2	<0.25	26	4	20	4	0	0.0	H/R	6.2
IPP29	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.4	5	26.0	112	12	102	70	<0.005	<0.05	<0.2	<0.25	32	24	41	24	0	2.0	148	4.6
IPP30	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.3	5	30.0	131	12	134	76	0.006	<0.05	<0.2	<0.25	58	30	41	30	0	0.6	35	2.2
IPP31	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.4	5	7.2	34	11	48	40	<0.005	<0.05	<0.2	<0.25	8	4	16	4	0	0.7	13	5.4
IPP32	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.8	5	12.0	42	13	62	40	0.007	<0.05	3.5	<0.25	22	3	16	3	0	1.0	20	6.4
IPP33	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.3	5	7.2	54	12	58	52	<0.005	<0.05	0.6	<0.25	6	11	31	11	0	0.0	H/R	5.9
Minimum	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.1	5	2.0	26	10	34	28	0.006	<0.05	0.2	<0.25	0	1	11	1	0	0.0	13	2.2
Maximum	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	7.4	5	53.0	278	17	162	90	0.008	<0.05	485.0	<0.25	134	30	143	30	0	2.6	165	6.6
Average	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	6.9	5	14.2	59	13	68	46	0.006	<0.05	47.3	<0.25	22	8	27	8	0	1.2	132	5.0

Table 5: Results of chemical analyses conducted on stream sediments.

NO	Ag ppm	Al %	As ppm	B ppm	Ba ppm	Bi ppm	Ca ppm	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Hg ppm	K ppm	Mg ppm	Mn ppm	Mo ppm	Na ppm	Ni ppm	Pb ppm	Sb ppm	Sn ppm	Ti %	U ppm	W ppm	Zn ppm
IPP(S)01	0.3	1.2	-	-	26	5	133	1	1	2	4	0.8	0.02	503	450	71	1	68	1	18	1	5	-	5.0	-	24
IPP(S)02	0.1	1.9	-	-	26	8	180	1	2	2	8	1.0	0.08	743	935	84	1	238	1	28	1	5	-	8.2	-	40
IPP(S)03	0.3	2.0	-	-	40	7	628	1	2	2	46	1.2	0.06	753	740	117	1	195	1	29	1	15	-	7.9	-	61
IPP(S)04	0.1	0.8	-	-	28	4	298	1	1	2	4	0.4	0.02	233	290	79	1	243	1	11	1	5	-	3.8	-	34
IPP(S)08	0.1	2.2	-	-	40	6	360	1	2	4	6	0.9	0.04	438	320	110	1	185	1	20	1	15	-	4.1	-	22
IPP(S)09	0.1	1.6	-	-	34	8	273	1	1	2	5	0.8	0.02	780	500	78	1	110	1	24	1	5	-	6.8	-	35
IPP(S)10	0.1	2.0	-	-	28	8	324	1	1	2	4	0.8	0.04	476	338	50	1	105	1	28	1	5	-	3.8	-	23
IPP(S)11	0.1	1.5	-	-	50	10	1520	1	1	3	12	0.7	0.02	450	630	139	1	93	1	24	1	5	-	18.1	-	34
IPP(S)12	0.1	1.6	-	-	32	8	1390	1	1	3	5	0.7	0.02	380	580	123	1	183	1	20	1	5	-	13.3	-	26
IPP(S)13	0.1	2.3	-	-	51	8	330	1	1	3	10	0.4	0.08	445	250	53	1	133	1	43	3	5	-	7.2	-	24
IPP(S)14	0.8	1.4	-	-	42	10	490	1	2	4	17	0.9	0.10	363	500	70	1	98	1	19	1	25	-	7.9	-	52
IPP(S)15	0.4	1.6	-	-	46	11	1003	1	2	3	12	0.7	0.06	413	635	125	1	85	1	20	1	15	-	7.9	-	31
IPP(S)16	0.1	1.9	-	-	64	10	713	1	2	6	9	0.8	0.18	410	470	122	1	128	2	25	1	25	-	4.9	-	56
IPP(S)19	0.1	3.7	-	-	44	13	513	1	2	5	10	1.5	0.16	470	262	42	1	93	2	31	1	15	-	5.0	-	22
IPP(S)24	0.1	1.9	-	-	36	3	358	1	2	3	60	0.8	0.04	503	582	122	1	45	1	19	1	5	-	6.2	-	28
IPP(S)27	0.1	1.0	-	-	34	6	678	1	1	2	7	0.7	0.04	263	825	122	1	98	1	15	2	5	-	6.0	-	44
IPP(S)29	0.1	1.2	-	-	34	8	890	1	2	3	12	0.8	0.12	316	952	140	1	88	1	14	1	5	-	7.0	-	58
IPP(S)30	0.4	2.3	-	-	54	14	473	1	3	5	6	1.3	0.08	723	582	112	1	85	2	26	1	25	-	6.2	-	26
IPP(S)31	0.1	1.0	-	-	32	2	875	1	1	2	8	0.7	0.02	273	905	120	1	90	1	15	2	15	-	11.7	-	46
IPP(S)33	0.1	1.6	-	-	65	7	383	1	1	4	11	0.6	0.04	433	362	69	1	88	1	25	2	50	-	4.2	-	60
Minimum	0.1	0.8	-	-	26	2	133	1	1	2	4	0.4	0.02	233	250	42	1	45	1	11	1	5	-	3.8	-	22
Maximum	0.8	3.7	-	-	65	14	1520	1	3	6	60	1.5	0.18	780	952	140	1	243	2	43	3	50	-	18.1	-	61
Average	0.2	1.7	-	-	40	8	591	1	2	3	13	0.8	0.06	468	555	97	1	123	1	23	1	13	-	7.3	-	37

Table 6: Results of chemical analyses conducted on residual soil.

NO	Ag ppm	Al %	As ppm	B ppm	Ba ppm	Bi ppm	Ca ppm	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Hg ppm	K ppm	Mg ppm	Mn ppm	Mo ppm	Na ppm	Ni ppm	Pb ppm	Sb ppm	Sn ppm	Ti ppm	U ppm	W ppm	Zn ppm
IPP(S)02	0.2	2.1	-	-	38	8	300	1	1	3	5	1.3	-	500	458	47	1	88	1	33	1	15	-	4.3	-	33
IPP(S)04	0.3	2.3	-	-	82	9	828	1	2	8	9	1.6	-	755	692	133	2	153	2	54	1	25	-	8.2	-	160
IPP(S)07	1.1	1.9	-	-	72	14	68	1	2	4	3	1	-	493	352	35	1	105	1	59	1	5	-	12.4	-	32
IPP(S)15	0.2	3.1	-	-	60	12	698	1	2	4	5	1.3	-	595	615	86	1	83	1	32	1	25	-	6.3	-	67
IPP(S)16	0.6	3.7	-	-	52	15	208	1	3	5	7	1.5	-	490	268	205	1	103	1	50	1	25	-	5.3	-	88
IPP(S)20	0.4	1.6	-	-	56	8	88	1	2	3	4	0.6	-	438	435	104	1	103	1	16	1	15	-	5.2	-	30
IPP(S)21	0.1	1.4	-	-	56	8	90	1	1	2	3	0.6	-	364	395	78	1	86	1	8	1	15	-	5.3	-	24
IPP(S)23	0.6	3.3	-	-	62	15	138	1	3	5	5	1.5	-	658	558	84	1	78	2	32	1	25	-	8.3	-	39
IPP(S)26	0.6	2.4	-	-	58	11	615	1	3	4	22	1.5	-	518	970	137	1	113	1	29	1	5	-	13.2	-	40
IPP(S)28	0.1	4.5	-	-	75	14	425	1	3	8	9	1.5	-	908	865	95	1	105	3	31	1	35	-	7.9	-	58
Maximum	1.1	4.5	-	-	82	15	828	1	3	8	22	1.6	-	908	970	205	2	153	3	59	1	35	-	13.2	-	160
Minimum	0.1	1.4	-	-	38	8	68	1	1	2	3	0.6	-	364	268	35	1	78	1	8	1	5	-	4.3	-	24
Average	0.4	2.6	-	-	61	11	346	1	2	5	7	1.2	-	572	561	100	1	102	1	34	1	19	-	7.6	-	57

Habibah, T., 2000. Kajian Geokimia Alam Sekitar, Paya Terubong - Relau, Pulau Pinang. *Jabatan Penyiasatan Kajibumi Laporan* GBI/00.

Ismail C.M. and Mohd Azmer, A., 1999. Kajian Hidrogeologi Bagi Projek Kajian Integrasi, Kawasan Paya Terubong - Relau, Pulau Pinang. *Jabatan Penyiasatan Kajibumi Laporan* GPH 3/99.

Lai, K.H., 1999. Photo-interpretation of the Paya Terubong - Relau Area, Penang Island. *Geol. Surv. Dept. Rep.* FG2/99.